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# Magnetoresistance in Electrodeposited Cobalt Based Alloys: Influence of Multinary Alloy Combination

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***Abstract***

*Electrodeposited alloys and multilayers which unveils GMR effect, gained lot of attention in modern technology. This type of films and multilayers has great potential in technological applications, mainly in the field of Magnetoresistive sensors and MEMS devices. In past few years cobalt based magnetic alloys were vastly studied because it offers an interesting magnetic and electrical properties over other alloys. This paper deals with the investigation of preparation and magnetic behavior of electrodeposited cobalt based multinary alloys. Structural and morphological properties of the alloys were confirmed using X-Ray diffractogram and FE-SEM micrographs. Magnetic behavior of the alloys were studied using B-H loop. The magnetoresistive properties were studied using four probe technique. From the investigation it is concluded that the alloys exhibits high crystalline properties with a suitable GMR Effect for the application of Magnetoresistive Sensors.*

***Keywords :*** *Cobalt Alloys, Electrodeposition, GMR Films, Magnetoresistive Sensors, Multinary Alloys.*

## 1. INTRODUCTION

Development of magnetic alloys with good magnetic moments are highly required in many areas such as magnetic induction writing heads, magnetic sensors and other magnetic-MEMS devices (Kim *et al.* 2003; Hong *et al.* 1999; Kohmoto, 1991). This type of magnetic alloys can be prepared using many methods. Over other methods electrodeposition is commonly used, it has several advantages such as good deposition rate, film composition, cost effectiveness also electrodeposited alloys offers good mechanical stability and magnetic properties (Tsynlsaru *et al.* 2009; Bodaghi and Hosseini, 2012). From the recent research it is clearly concluded that cobalt based magnetic alloys has better magnetic properties which is essential for Magnetoresistive sensors and MEMS devices. Over the years cobalt was alloyed with many magnetic and non-magnetic metals as binary, ternary alloys in order to obtain magnetic alloys with good magnetoresistive properties. Present work is devoted to study the preparation and characterization of cobalt based multinary alloys. Also the influence of alloy combination on the magnetoresistive properties was studied.

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## 2. EXPERIMENTAL PROCEDURE

Tri sodium citrate based sulfate electrolyte composed with cobalt sulfate, Nickel sulfate, sodium tungstate, sodium hypophosphite and boric acid were adopted to electrodeposit CoNiWP films. (Rajkumar *et al.* ) Commercial copper plate and nickel rod is used as cathode and anode respectively. The chosen salts were dissolved in distilled water and the pH of the electrolyte was maintained as 5. The deposition parameters such as deposition time, temperature, and current density were optimized as 30 minutes, room temperature, and 10 $mA/cm^2$. After the deposition cathodes were carefully removed and dried well. Structural properties of the electrodeposited CoNiWP alloys were investigated using X-Ray diffractogram. Morphological properties and Constituents in the alloys were confirmed using FE-SEM micrographs and EDAX pattern. Magnetic properties such as magnetoresistivity and B-H loop were studied to know the influence multinary combination on magnetic properties.

## 3. RESULTS & DISCUSSION

XRD Characterization was conducted to study the structural properties of the film. The obtained X-Ray diffractogram of CoNiWP films prepared at optimized deposition parameters is shown in Fig. 1. It reveals the formation of high crystalline films with (220) plane as the predominant orientation. The grain size of the deposits in the films were identified as in the range of nanometer (18 nm), it was calculated with scherer formula.

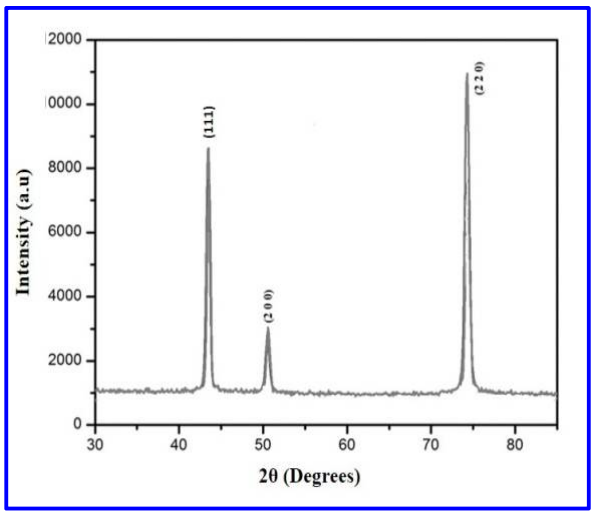


**Fig. 1: X-ray Diffractogram of CoNiWP Films Deposited at Optimized Deposition Parameters**

The constituents of the film were studied using EDAX pattern and it is shown in Fig. 2. The presence of all relevant elements was confirmed along with some impurities.Advent of Cu peaks are possibly from the copper substrate (Rajkumar *et al.* ; Ezhil Inban Manimaran *et al.* 2018). Fig. 3 shows FE-SEM micrographs of CoNiWP films. Micrographs confirms the formation of uniform deposition with agglomerated layer in the film (Nor Azrina Resali *et al.* 2013). The mobility of the ions in electrodepositioncauses higher deposition rates this results in the formation of layer like deposition.

The magnetic behavior of CoNiWP film was studied using VSM. Fig. 4 shows the magnetic hysteresis loops (B-H curve) of the film and table 1 shows the obtained values. It confirms the soft ferromagnetic nature of the films. The coercivity value of the films found to be as slightly higherover ternary alloys. The aggregation of phosphorus and tungsten in the multinary combination strongly affect the granular boundaries which results in the variation of coercivity, this aspect is in good contract with the microstructural properties of the film. Along with grain size nickel also a considerable factor, for the low coercivity nature (Shorowordi *et al.* 2017; Daheum Kim *et al.* 2003 ).

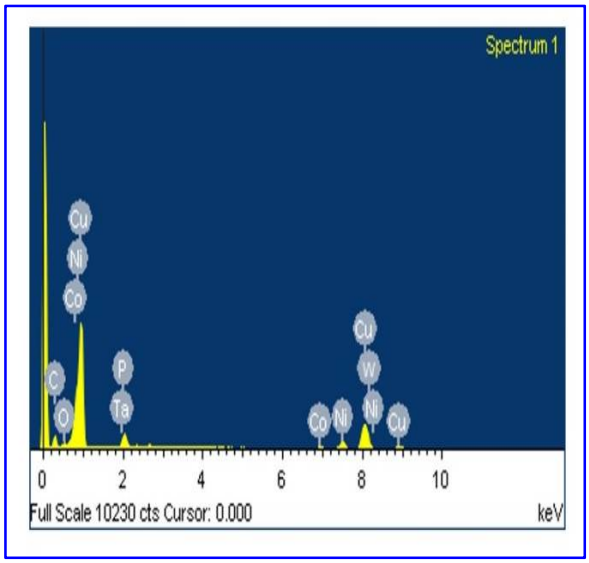


**Fig. 2: EDAX Pattern of CoNiWPFilms**

**Table 1. Magnetic properties of CoNiWP films deposited at optimized deposition parameters**

| Substrate | Current Density ($mA/cm^{-2}$) | Deposition Time (Minutes) | Magnetic Saturation ($M_s$) Emu | Remanence ($M_r$) Emu | Coercivity ($H_c$) $O_e$ | Squareness |
|---|---|---|---|---|---|---|
| Copper | 10 | 30 | 1.7560 | 440 | 2784 | 250 |

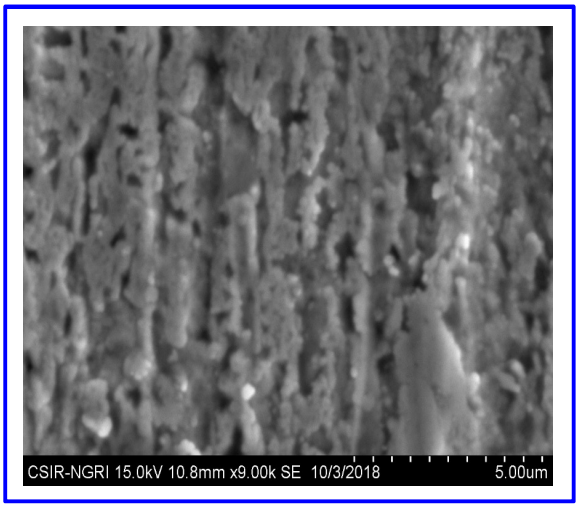


**Fig. 3: FE-SEM micrographs of CoNiWP films deposited at optimized deposition parameters**

Fig. 5 shows the magnetoresistance response of CoNiWP film prepared at optimized deposition parameters. It has been recorded at fields below 80 Guassand the resistance values were calculated with the formula $(R_H-R_0).100/R_0$. CoNiWP films exhibits Giant magnetoresistance (GMR) characteristics similar to the ternary films reported earlier [6].The variation in resistance was recorded as18% to 36 % and the resistance values are found to be gradually decreased with respect to the applied field. The presence of phosphorus and tungsten in the multinary combination strongly affect the GMR behavior. But the resistances of the films were significantly lowercompared topreviously reported cobalt tungsten alloy films.

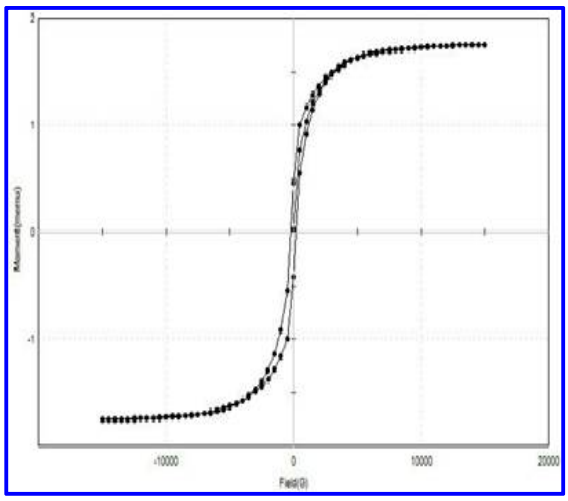

**Fig. 4: Hysteresis loop of CoNi WP films deposited at optimized deposition parameters**

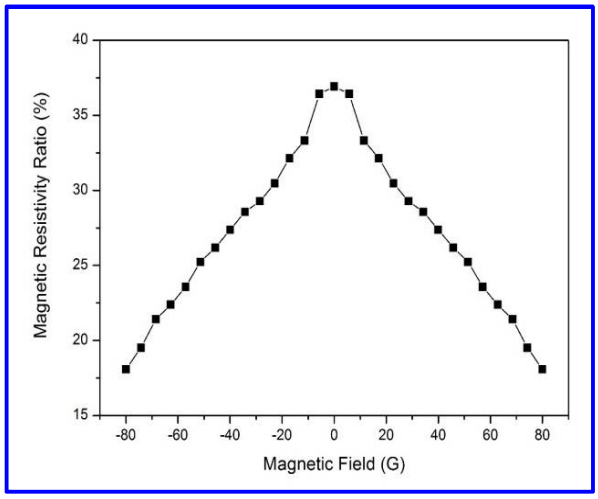


**Fig. 5 : Magnetoresistance of CoNi WP films deposited at optimized deposition parameters**

## 4. CONCLUSION

Structural changes and magneto resistance of electrodeposited CoNiWP alloy films were investigated by galvanostatic technique. From the investigation it is find out that the CoNiWP films has good crystalline nature. Morphological studies reveal that the films were deposited as uniform and well covered over the substrate. EDAX pattern confirms the presence of relevant peaks. B-H loop of the CoNiWP alloy is recorded using Vibrating sample magnetometer, it confirms ferromagnetic nature in the alloys. Magnetoresistivity studies using four probe method reveals the GMR Effect in the alloys.

From this it is clearly concluded that prepartionof multinary alloy is quite similar to ternary alloys, but it strongly influence the film deposition and microstructure which results in the formation of CoNiWP films with GMR nature and marginally better magnetic properties compared to ternary combinations.

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